IMAGE SEPARATOR FOR STEREOSCOPIC FUNDUS PHOTOGRAPHY*†

BY

T. J. FFYTCHÉ

Moorfields Eye Hospital, High Holborn, London

THE recent publication of stereoscopic manuals of fundus photography (Blodi and Allen, 1964; Hoyt and Beeston, 1966) has demonstrated the great potentials of this form of investigation. A stereoscopic photograph is not only an excellent medium for teaching, but is also of great diagnostic value in presenting a magnified three-dimensional image of the fundus, which may be examined in detail at leisure and compared readily with the ophthalmoscopic appearance or correlated with the fluorescein angiogram. In addition, it can provide an objective record of the progress of ocular lesions which are themselves three-dimensional in nature.

An instrument is described that has been designed to be used in conjunction with a fundus camera to take stereoscopic photographs.

Although the history of stereoscopic fundus photography dates back to the work of Thorner (1909), it is only recently that advances in photographic equipment, in particular the electronic power-pack, have made this form of photography more practicable.

It is conceded that the only truly quantitative method of stereophotography entails the use of simultaneous exposures, but to produce a suitable fundus camera to give simultaneous exposures is technically difficult; although such cameras do exist (Norton, 1955; Donaldson, 1965), they are very expensive and, being in a limited field of photography, are at present beyond the range of most photographic units.

Stereoscopic photographs can be obtained more easily though less accurately by taking successive photographs and altering the optical axis of the camera between exposures. This dual-exposure method, known as relative stereophotography, has been made possible by the advent of the rapidly recharging electronic flash unit which reduces the time between exposures; the pictures obtained by this method give a qualitative stereoscopic effect although their quantitative value is variable.

Several different methods for altering the optical axis of the camera have been devised; these include rotating the camera (Stenstrom, 1960) moving it laterally (Allen, 1964), moving the patient's fixation (Norton and Sullivan, 1958), and altering the direction of the optical system by an image-separating device (Allen, Kirkendall, Snyder, and Frazier, 1966).

The main disadvantages of all forms of dual-exposure stereophotography are that such factors as the illumination, the focus, or the position of the retinal image may change between the two exposures so that the stereoscopic effect is lost or distorted. In addition, a reliably constant depth effect is difficult to achieve, as it is practically impossible to duplicate

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† Address for reprints: Moorfields Eye Hospital, High Holborn, London, W.C.1.

the alteration in the position of the image to give a constant stereoscopic effect. Thus the quantitative value of this type of photography is not reliable.

Several of these problems can be reduced by the use of an image separator. This is a device which, when inserted between the camera and the patient's eye, can alter the direction of the rays of light entering and leaving the optical refracting system. Such a device has the advantage that a change in the direction of the light pathway can be made and reversed rapidly, thereby enabling the photographer to match up the images of the fundus in intensity of illumination and focus before he is committed to taking a pair of stereoscopic photographs. An additional advantage is that throughout the procedure the patient's fixation and the camera remain stationary.

The direction of the light may be altered by several types of image-separating devices. These include rotating prisms, mirrors, and parallel-sided plates of glass (Allen and others, 1966), and a modification of the Allen Stereoscopic Separator has been designed which can be adapted to most fundus cameras and allows a rapid and measurable alteration of the direction of the light beam (Fig. 1).

FIG. 1.—Photograph of image separator. The Perspex disc is rotated by the milled screw at the top of the instrument. The angle regulator is sited beneath the disc.

Apparatus

The principle of cornea-induced parallax previously described by Allen (1964) is utilized, in which stereoscopic images of the fundus can be obtained from the refraction of two parallel beams of light incident on the cornea (Fig. 2, overleaf). The separation of the optical light pathway of the fundus camera is achieved by the insertion of a parallel-sided Perspex plate between the camera and the eye. By tilting this plate around a vertical axis, any beam of light traversing it will be deviated laterally along a parallel course (Fig. 3, overleaf).

An interval of 3.5 mm. between the two parallel light beams incident on the cornea has been found to reproduce a stereoscopic system giving the equivalent of the binocular parallax of an

FIGS 2 and 3.—Diagrams of light pathways used in relative stereophotography (after Allen).

average person viewing an object held about 9 in. from the eye, and thus represents as nearly as possible the normal depth relationships at the posterior pole. This beam separation can be obtained by rotation of the Perspex plate through an angle of approximately 45° , and the image separator can be adjusted to rotate through this angle.

Procedure

Stereoscopic photography with the image separator can be performed by a single photographer. It is important that the patient's pupils are maximally dilated in order to include within the pupillary aperture as much of the incident light as possible in each position of the instrument.

The image separator is fitted onto the barrel of the camera as near as possible to the objective lens in order to avoid touching the patient's face. To check that there is correct alignment, the plate is positioned perpendicularly to the beam of light emerging from the camera. In this position the photographer will see the reflection of the viewing light when looking through the camera eyepiece. The position of the instrument should then be adjusted until this reflection lies in the centre of the cross-wires of the eye-piece and has a horizontal excursion when the plate is moved laterally.

With the plate in one lateral position (traditionally tilted to the observer's right) the image of the fundus is focused as for ordinary fundus photography; it may be necessary to increase the illumination of the flash but the aperture of the camera need not be altered.

The Perspex plate is then rotated to the opposite side to give a beam separation of 3.5 mm. and the position of the camera is adjusted until the two images obtained by this separation are comparable in illumination and focus. The rapid to and fro movement of the image separator facilitates this manoeuvre and the position of the light beams on the cornea is shown in Fig. 4.

FIG. 4.—Diagram to show optical effect of image separator (after Allen).

When these conditions have been satisfied the camera is fixed and a pair of photographs is taken in rapid succession, altering the angle of the image separator between exposures. The patient is instructed to hold fixation during the procedure and although reflex blinking occurs most patients are able to do this.

The stereoscopic pairs are mounted in standard stereoscopic mounts with the picture taken when the instrument is in the right position (*i.e.* the first position) mounted in front of the right eye; a depth effect proportional to the normal scale can be obtained if the deepest parts of the fundus, for example the bottom of the optic disc, are mounted 63 mm. apart horizontally. The pictures may be viewed through a simple stereoscopic viewer.

When pupillary dilatation is poor, the image separation may have to be reduced so that sufficient light enters the pupil for satisfactory photography, and the instrument can be so adjusted. This reduction in beam separation will give less stereoscopic effect, but by recording the amount of image separation the same conditions can be reproduced and some form of quantitative stereopsis can be achieved.

If this standard procedure is adopted, most of the inaccuracies of focus and illumination inherent in other methods of dual-exposure stereophotography can be reduced, and since the instrument allows the conditions to be duplicated accurately some approach to the quantitative measurement and recording of depth may be made. There are, of course, the general problems of patient co-operation, refractive errors, pupil dilation, and opacities of the ocular media that can occur with any routine fundus photography, but even a poor stereoscopic fundus photograph will yield a great deal more information than an ordinary colour transparency, and often an annoying light reflex or catoptric image present on one photograph will be masked when viewed binocularly with its fellow.

Summary

A modification of the Allen Stereoscopic Separator is described. It has the advantage that it is simple to use and can be adapted to most fundus cameras. It enables the photographer to obtain satisfactory dual-exposure stereoscopic photographs which can give some quantitative value to this kind of stereophotography.

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REFERENCES

- ALLEN, L. (1964). *Amer. J. Ophthalm.*, **57**, 13.
 ———, KIRKENDALL, W. M., SNYDER, W. B., and FRAZIER, O. (1966). *Arch. Ophthalm. (Chicago)*, **75**, 192.
 BLODI, F. C., and ALLEN, L. (1964). "Stereoscopic Manual of the Ocular Fundus in Local and Systemic Disease". Mosby, St. Louis.
 DONALDSON, D. D. (1965). *Arch. Ophthalm. (Chicago)*, **73**, 253.
 HOYT, W. F., and BEESTON, D. (1966). "The Ocular Fundus in Neurologic Disease". Mosby, St. Louis.
 NORTON, H. J., and SULLIVAN, C. T. (1958). *A.M.A. Arch. Ophthalm.*, **60**, 455.
 NORTON, H. J. (1955). *Amer. J. Ophthalm.*, **40**, 809.
 STENSTROM, W. J. (1960). *Arch. Ophthalm. (Chicago)*, **64**, 935.
 THORNER, W. (1909). *Klin. Mbl. Augenheilk.*, **47** (1), 481.