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Ophthalmic Photography

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Preface

Since the advent of fluorescein angiography, there has been a marked increase in the demand for qualified ophthalmic photographers. The purpose of this book is to present various ophthalmic photographic techniques in order that the novice as well as the experienced ophthalmic photographer and the interested ophthalmologist can approach these techniques in a practical manner.

In response to this need for trained ophthalmic photographers, the Ophthalmic Photographers' Society was founded in 1969. Originally a small group of 10 people, it is now an international group with more than 500 members. The society has local and national courses that lead to certification. This program was developed by a few hardworking persons who had the foresight to appreciate its necessity.

In February 1981, after 23 years of association with medical institutions such as Duke University School of Medicine, the Bascom Palmer Eye Institute at the University of Miami School of Medicine, the Jefferson Medical College and the Wills Eye Hospital of Philadelphia, and the Cullen Eye Institute at Baylor College of Medicine, Houston, I decided to enter the exciting world of private enterprise. In addition to starting my Ophthalmic Photography and Ultrasonography Service, I have joined Akorn, Inc., and Kowa, Optimed, Inc., as a consultant.

I would like to thank the innumerable ophthalmologists, ophthalmic photographers, and friends who have played a major role in the development of my career as an ophthalmic photographer and ultrasonographer. I am especially indebted to Doctors Edward W. D. Norton, J. Donald M. Gass, and David Paton.

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Finally, I wish to express my appreciation to the contributing authors. Without their enthusiasm and expertise, this book would not have been possible.

J. J.

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Contents

Evolution of Ophthalmic Photography

R. HURTES

In striving for scientific precision, medicine has always sought accurate methods to document clinically witnessed disease processes. The eye is the only organ in the body that may be precisely examined in situ; because of its accessibility and transparency, pathologic processes as well as normal physiology can be observed in living tissue. The invention of the ophthalmoscope in 1850 and the slit lamp in 1911 brought ophthalmology to the level of an exact science by providing a unique opportunity for clinical observation beyond all other branches of medicine.

It seems strange that the eye should be compared so often to a camera when it was the eye that sparked the imagination for the development of the camera. Christopher Scheiner, a German Jesuit, proved in 1625 that the eye forms images directly from light. He removed the opaque sclera from the back of an animal eye, held the eye in front of his own, and pointed it at an object. To his delight, the inverted image of the object was visibly projected onto the retina of the animal eye. Actually, Father Scheiner had only confirmed the proposal made by Leonardo da Vinci a century earlier. Leonardo demonstrated his theory of how the eye sees by using two adjacent rooms, one well lighted and the other dark. He made a tiny hole in the wall between the rooms and, while standing in the dark room, held a piece of paper close to the small aperture. When the paper was adjusted to the proper distance from the hole, inverted images of objects in the lighted room were projected onto the paper. Leonardo did not invent the *camera obscura,* but he was the first to understand its principles and their relationship to the eye.

The seventeenth century was a creative period in the field of optics, and many studies were made of animal and human eyes. During this period, Lippershey invented the telescope and Galileo refined it. Another very important development was the formulation of the laws of refraction by thinkers such as Snell, Descartes, Hooke, and Newton. From these foundations, photography was to grow almost two centuries later.

Photography was born in 1826 when Nicéphore Nièpce photographed a sunlit garden from his window in Gras, France. The expo-

I would like to express my appreciation to Dr. Edward W. D. Norton, Dr. Joel Glaser, Mr. Jean-Marie Parel, and Miss Rose Beck for reading this chapter and offering suggestions for improvement, and to Mr. Joseph Goren for reproducing the figures.

sure time required for this first photograph was 8 hours! Thus it was proved that light images could be recorded and kept permanently.

Since 1888, when George Eastman developed his "everyman's camera," the Kodak, photography has become a means of documentation in which almost everyone can participate. However, not until 1889, when Eastman developed flexible film to replace the cumbersome glass plates, did photography become an increasingly popular and professional phenomenon. The age of tripods, portable darkrooms, and technical magic was gone, and the age of instant reproduction had arrived.

Since Eastman's time, every new camera has further freed the photographer to concentrate on the subject rather than on photographic techniques, and the act of taking pictures has become swifter and simpler. In ophthalmology, improved and simplified methods of calibration and technique have enabled accurate comparison between photographs taken at different sittings. Thus, photography and ophthalmology joined hands, and a solid union was created.

Fundus Photography

Since the day that physicians could first see into the back of the living eye, attempts have been made to document their observations accurately with elaborate drawings. The details of these drawings were painstakingly obtained through a laborious process for the artist and a fatiguing ordeal for the patient; however, some magnificent works were created. For instance, one should look at the beautiful atlases of Liebrecht [36] and Oeller [48], who painted on canvas with oils to obtain likenesses of their observations as seen through the magic window of the ophthalmoscope. (An interesting footnote is that Liebrecht eventually gave up ophthalmology to devote himself to painting.)

In 1907, Dimmer published the first textbook of fundus photographs (Fig. 1-1), and after his death his student, Pillat, published an atlas [15]. This volume was followed by Bedell's book [4] in 1929, which was the first English-language atlas to contain photographs and the first demonstration of stereophotographs.

Good fundus photographs were difficult to obtain since large portions of the fundus were obscured by the reflexes from ocular tissues caused by the lamp used for exposure of the film. Jackman and Webster [31] took the first human fundus photograph in 1886; however, the optic nerve appeared as an irregular blotch and the arteries and veins were not visible.

Using his own method of photography, Howe [29] in 1887 documented a fundus photograph in which the disc was perfectly distinct and the vessels were so clear that arteries could be distinguished from veins. He described the difficulties encountered in taking the picture

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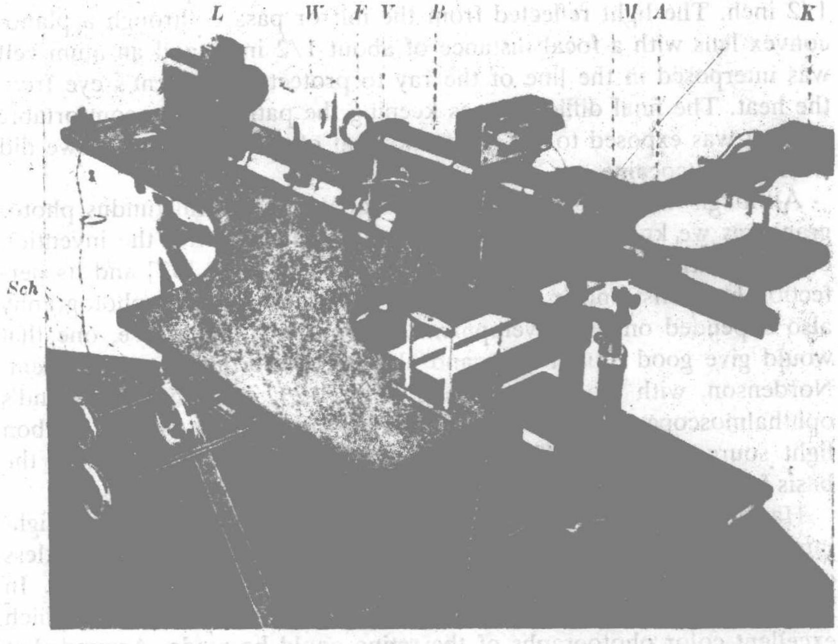

Fig. 1-1. Dimmer's fundus camera. L = *light source;* W = *water cooling system;* F = *fixation point;* V = *shutter apparatus;* B = *illumination system;* M = *metal mirror;* A = *observation system;* K = *camera;* Sch = *knobs to move table.* (*Condensing lens not shown.*) (*From F. Dimmer and A. Pillat,* Atlas photographischer Bilder des Menschlichen Augenhintergrundes. *Leipzig: F. Deuticke, 1927.*)

and the manner in which these difficulties were overcome. First, there was the problem of photographing the red reflection. The plate was made sensitive by an elaborate treatment with the following solution: "erythrosine, 1.5 drachm; ammonia (88°), 1 drachm; alcohol, 6 ounces; nitrate of silver, 1 drachm. Converted into chloride with hypochloric acid, thoroughly washed, and redissolved in ammonia."

The second problem was finding the proper means of projecting the fundus onto the plate with the camera placed in front of the eye. Howe found that the demonstration ophthalmoscope, which enabled two observers to view the fundus simultaneously, was inadequate. He conducted many experiments using lenses of different powers, various sized apertures in concave mirrors, a variety of camera lenses, and daylight and artificial light. He finally adopted the procedure of placing an ordinary Argand gas burner (a lamp with a tubular wick that admits a current of air inside as well as outside the flame) in the focal point (13 inches) of a concave mirror that had an aperture of about 1/2 inch. The light reflected from the mirror passed through a plano-convex lens with a focal distance of about 1/2 inch, and an alum cell was interposed in the line of the ray to protect the patient's eye from the heat. The final difficulty was keeping the patient's eye comfortable when it was exposed to the glare and heat of the lamp; this Howe did with topical cocaine.

Although these procedures were adequate, successful fundus photographs as we know them today were possible only after the invention of the reflexless ophthalmoscope by Thorner in 1899 [57] and its perfection by Gullstrand in 1910 [25]. The success of good photography also depended on the development of a proper light source, one that would give good illumination and also be comfortable to the patient. Nordenson, with the help of Zeiss (Fig. 1-2), modified Gullstrand's ophthalmoscope and developed a fundus camera that used a carbon light source [43, 44]. The general principle of this camera was the basis for all subsequent instruments.

Hartinger, in 1930, replaced the carbon arc light source with a high-intensity incandescent lamp; later, in 1936, he developed the reflexless ophthalmoscopic lens with a small black dot in the middle [28]. In 1953, Hansell and Beeson [26] described a xenon arc tube with which excellent color photographs of the retina could be made. Around that time, Ogle and Rucker [49] made an important contribution to fundus photography with the incorporation of their electronic flash, which was developed at about the same time as the xenon light source. Drews [19] further perfected the electronic flash in 1957. Donaldson [17], with the help of Edgerton, perfected in 1964 a special flashtube for use in his stereocamera which emitted light from the end of the tube, thus allowing greater intrinsic brilliance.

In the earliest years of fundus photography, a major problem (besides the reflexes from light sources and from the eye itself) was movement of the patient's eye during film exposure. Exposure times had vastly decreased from the 8 hours that Nièpce needed to photograph his garden, but even a time of several seconds was too long. Technical advances in light sources; tremendous improvements in film quality, developing techniques, and filter efficiency; and the reduction of exposure time to milliseconds vastly improved the quality of photography. Beginning with Dimmer, who worked for 10 years perfecting his technique, scores of investigators have improved and simplified the procedure for fundus photography.

Until 1972, only a small area (about 30 degrees) of the fundus could be photographed on a single exposure; larger areas were documented by photographing overlapping fields of the fundus and piecing these pictures together to form a mosaic of the larger area. However,

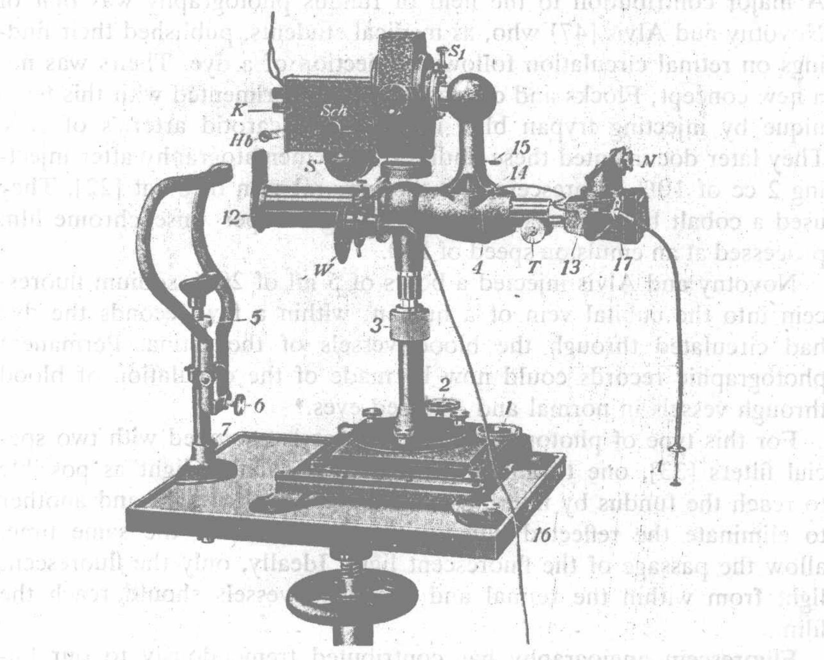

Fig. 1-2. Zeiss-Nordenson fundus camera. (From H. Hartinger, Ein neue reflexfreie Ophthalmoskoplinse für die Zeiss-Nordensonsche Netzhautkammer. Z. Ophthalmol. Optik. *24 : 137, 1936.)*

exciting work may make it possible to photograph the entire retina on one exposure by means of a Japanese-designed optical fiber system placed in a circular fashion into a corneal contact lens. This technique illuminates the entire retina and allows reflection-free observation [51].

Fundus Cinematography

In 1934, Lijo Pavia [37] substituted a motion picture camera for the plateholder in the Nordenson camera and successfully recorded the pulsations of the retinal vessels. Bailey and Swan [3], in 1959, described a simple, practical camera that eliminated the high concentration of light formerly required for cinematography. It consisted of three units: (1) a mounted +20 D condensing lens such as that used in indirect ophthalmoscopy; (2) a paraxial illumination system with a device for changing magnification (the body of a Zeiss dissecting microscope); and (3) the 16-mm Arriflex camera, containing a through-the-lens continuous focusing device. This camera permitted the detection of vessel changes that were not discernible with ordinary direct ophthalmoscopy or with serial single-frame photographs.

Fluorescein Angiographic Photography

A major contribution to the field of fundus photography was that of Novotny and Alvis [47] who, as medical students, published their findings on retinal circulation following injection of a dye. Theirs was not a new concept; Flocks and colleagues had experimented with this technique by injecting trypan blue into the intracarotid arteries of cats. They later documented these findings with cinematography after injecting 2 cc of 10% fluorescein into the femoral vein of a cat [22]. They used a cobalt blue filter and 16-mm daylight Super Anscochrome film processed at an emulsion speed of 100.

Novotny and Alvis injected a bolus of 5 ml of 20% sodium fluorescein into the cubital vein of a human; within a few seconds the dye had circulated through the blood vessels of the retina. Permanent photographic records could now be made of the circulation of blood through vessels in normal and diseased eyes.

For this type of photography, the camera is equipped with two special filters [33], one to allow as much blue-exciting light as possible to reach the fundus by filtering out the green yellow light and another to eliminate the reflected blue-exciting light and, at the same time, allow the passage of the fluorescent light. Ideally, only the fluorescent light from within the retinal and choroidal vessels should reach the film.

Fluorescein angiography has contributed tremendously to our understanding of disease in the ocular fundus; moreover, it has added a new dimension to our understanding of the eye. We are now able to study the physiologic processes of the eye and to correlate new observations with anatomic knowledge. Over the past 15 years, this technique has forced physicians to observe the fundus more carefully than ever and therefore has contributed greatly to our understanding of the normal and diseased retina. Thus angiography has become an important tool for ophthalmologists through the medium of the camera.

Television Ophthalmoscopy

One of the newer developments in ophthalmic photography is the use of television for projecting ophthalmoscopic pictures of the eye [11]. Among the many advances in this area is a device for taping fluorescein angiograms in which a miniaturized television camera, a beamsplitter, and an optical relay are utilized in conjunction with the Zeiss retinal camera [59].

Stereoscopic Fundus Photography

Stereoscopic fundus photography has been attempted since 1909, when Thorner first tried to take two photographs through opposite halves of the pupil by inverting the camera [58] (Fig. 1-3). Many investigators have made an effort to obtain good stereographs, some by moving the

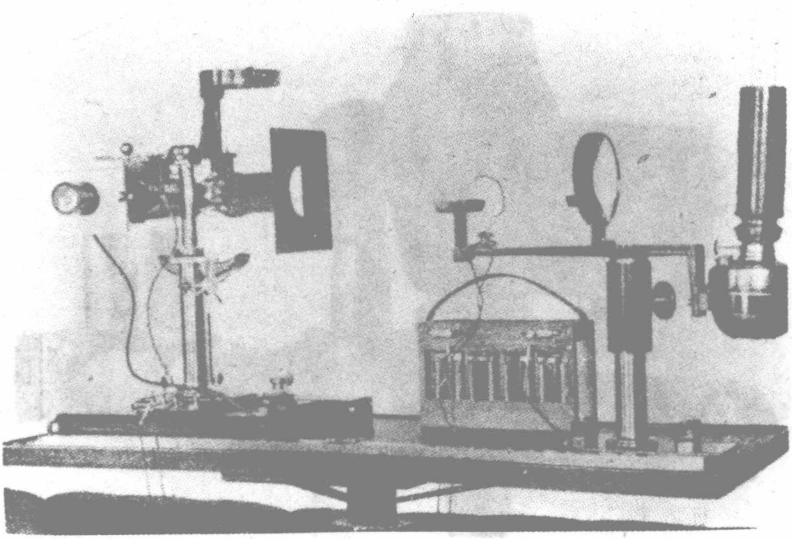

Fig. 1-3. Thorner's stereoscopic fundus camera. (From D. D. Donaldson, A new camera for stereoscopic fundus photography. Trans. Am. Ophthalmol. *62 : 429, 1964.)*

patient's eye very slightly between exposures [45], and others by moving the camera while the eye remained fixated [4] (Fig. 1-4).

Krakau [34] fitted his camera with appropriate prismatic devices for the photographic registration of depth. Allen [1] designed a system in which a cornea-induced parallax was utilized; the camera was directed through one side of a well-dilated pupil for the first exposure and, without any angulation, was moved to a parallel position on the other side of the pupil for the second exposure. The device could be positioned to shift the optical axis of the camera either horizontally or vertically. As is the case with many innovations, Allen's separator was mechanized by Parel and colleagues [50] and by Allen [7] at about the same time independently of each other. Parel's retinal camera consisted of an automatic filter-changing device, a data recording system synchronized with the dye injection and displayed on the film format separately from the fundus image, and the automated stereo system based on Allen's separator. The Allen separator is the basis for today's stereoscopic camera.

Regardless of the efficiency of Allen's technique, however, one must realize that it is still a serial, albeit instantaneous, procedure. In true stereoscopic photography, both views should be recorded simultaneously. To my knowledge, the only person to construct such a camera

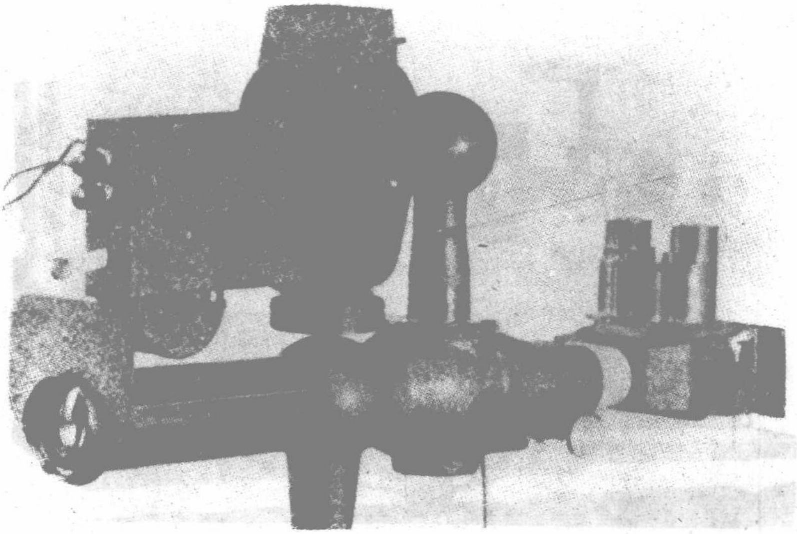

Fig. 1-4. Nordenson's stereoscopic fundus camera with binocular eyepieces. (From D. D. Donaldson, A new camera for stereoscopic fundus photography. Trans. Am. Ophthalmol. *62 : 429, 1964.)*

was Dr. Donaldson [17], who developed in 1964 an instrument based on the principles of indirect ophthalmoscopy (Fig. 1-5). To describe it simply, this camera integrated two fundus cameras using the same primary aspheric objective to take simultaneous photographs, and it incorporated a new electronic flash that provided adequate illumination for 35-mm color film. Binocular fundus images were seen while focusing. The camera was speedy and easy to operate, and the resulting stereogram was free of distortion and had a high degree of definition. The depth effect was absolutely reproducible.

Others have attempted to devise improved stereoscopic techniques. Mikuni and Yaoeda [42] developed a rapid system for taking serial photographs using the Allen separator. Saheb and coworkers [52] constructed a twin prism, mounted on the camera objective to reduce error between exposures, which took instantaneous stereophotographs with constant separation of images. However, this system created certain distortions (as one would expect when light is passed through a prism) and also required an 8-mm pupillary diameter, which would present a distinct obstacle in many patients.

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