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Abstract: We modified a Zeiss Model-211 photo slit-lamp by adding a fluorescein fundus photography barrier filter and compared its clinical usefulness for performing iris fluorescein angiography (FA) with two standard FA-capable photo slit-lamps, Zeiss 40-SL and Kowa SC-1200. We evaluated flash intensity, light transmission, filter transmission characteristics, density range on film in response to fluorescence, flash recharge time, and clinical applicability. We obtained the following results from Model-211, the 40-SL, and the SC-1200, respectively: maximum flash exposure, 500,000, 96,000, and 26,000 lux; light transmission from an objective lens through the camera, 350, 120, and 66 lux; minimum useful density of fluorescence, 0.9×10^{7}, 0.4×10^{-6}, and 0.8×10^{-6} g/ml; and flash recharge time, 2.0, 6.0, and 1.0 seconds. The filter permeability rates of the three devices were similar. Small iris vessels were seen more clearly with the modified Zeiss Model-211 than with the other two systems, although the exposure with each magnification must be varied because of the changing light transmission with each magnification. We conclude that our system is clinically useful and superior to other commercial units for imaging of small blood vessels.

Fluorescein angiography (FA) of the anterior segment is widely used to evaluate disease progression and treatment efficacy [1-5]. This technique requires a filter designed for use in a photo slit-lamp and a high-intensity light source to replace the beamsplitter intended for stereoscopic viewing. The new light source must also allow rapid serial angiography. Since devices meeting these conditions are more expensive than conventional photo slit-lamps, their widespread use is limited. In the present study, we modified an existing photo slit-lamp (Model-211, Zeiss Jena, Oberkochen, Germany) by adding a fluorescein fundus photography barrier filter. We report herein the angiographic results from this low-cost modification compared with other commercially available FA-capable photo slit-lamps.

Materials and Methods

Modifying the angiographic device - We used a Zeiss Model-211 photo slit-lamp (Fig. 1), one elbow of which was equipped with a filter pocket to accommodate a fluorescein angiographic filter between the observation and the illumination systems (Figs. 1, 2). We inserted an SB50 barrier filter (Spectrotech, Saugus, MA) into this pocket, and an SE40 (Spectrotech) exciter filter into another filter pocket in the illumination system (Fig. 1).

Comparison with conventional devices - We compared our modified Zeiss Model-211 with a Zeiss 40-SL (Fig. 3a) and a Kowa SC-1200 (Kowa, Tokyo, Japan) (Fig. 3b). Both the 40-SL and the SC-1200 are commercially available, FA-capable photo slit-lamps. We tested the following parameters:

Flash intensity - The flash intensity generated by each photo slit-lamp was measured using a photometer (Mastersix, Gossen, Germany) mounted at the focal length of each device. We measured all available electronic power options of each device.

Light transmission - The electronic flash was operated at the focal distance of each slit-lamp, and the quantity of light transmitted from the objective lens to the film was measured by a photometer (Mastersix) mounted on the film surface of the camera. For this

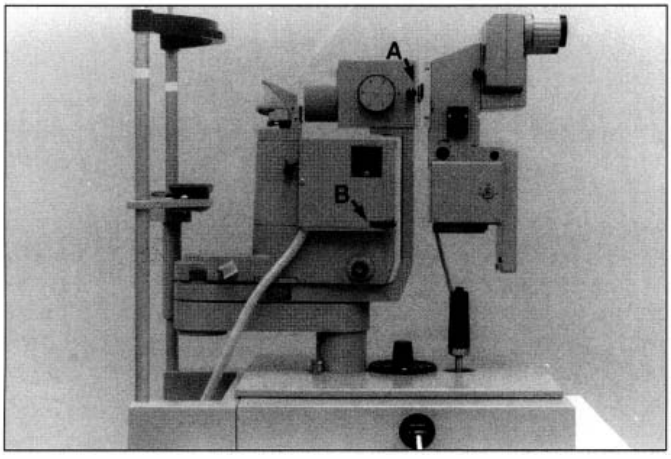


Figure 1: Modified photo slit-lamp (Model-211). A pocket for a barrier filter was added (A). The exciter filter was inserted into the built-in filter (B) with no additional modification necessary.

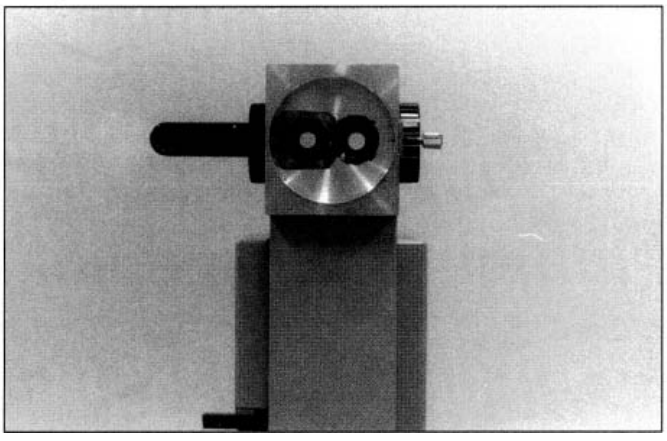


Figure 2: The pocket for the barrier filter (A of Fig. 1) as seen from the observation system by detaching the latter. The light entering through an objective lens is split into two equal beams. The pocket for the barrier filter was added to the left side leading to the angiographic camera.

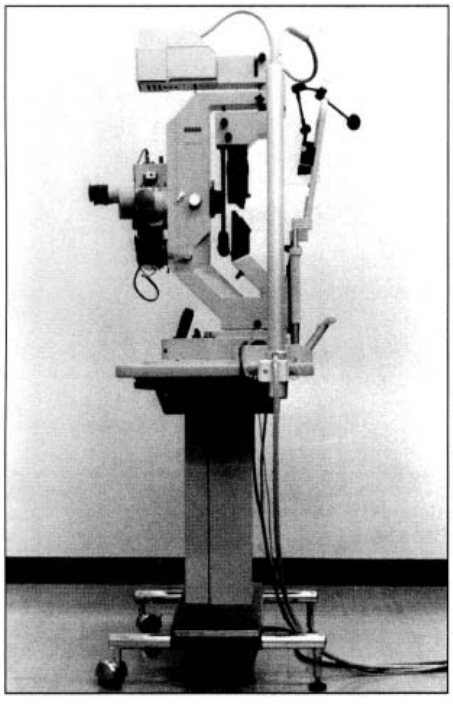
measurement, the lens aperture was opened maximally, and the focal plane of the camera was opened and shut in synchrony with the flash. We measured all available photographic magnification options of each device.

Filter characteristics - The fluorescein filters attached to each device, ie, the exciter and barrier filters, were measured for characteristic curves using a spectrophotometer (UV 160 Shimazu, Tokyo, Japan).

Effective density range in response to fluorescein - Sodium fluorescein was diluted with a 0.1 M phosphate buffered solution to $10^{-4} \times 10^{-7}$ girl and enclosed in a capillary tube that then was photographed on a black background using each slit-lamp. Following film development, the negatives were measured for optical density using a densitometer (Unigraphy UHG-101, Unique Medical, Tokyo, Japan).

The photographic conditions - The photographic conditions were as follows: photographic magnification 16x, lens maximally opened, and maximum flash intensity emitted. Kodak Tri-X pan film (ISO 400, Kodak, Rochester, NY) was used, and its sensitivity was enhanced four-fold with pushed development (producing an effective film speed of ISO 1600).

Flash recharge time - The flash recharge times between the first and the second flashes were measured.



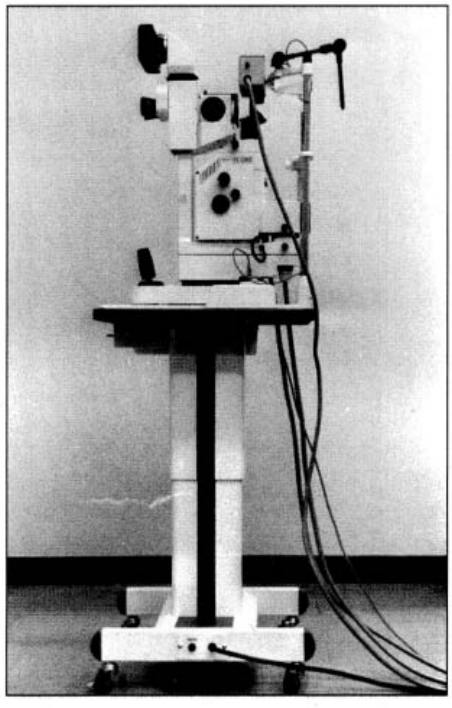


Figure 3: The slit-lamps compared with Model-211.

A) 40SL B) SC-1200

Clinical applicability - The same patient with rubeosis iridis diabetica underwent fluorescein angiography using each device. After sodium fluorescein (5 ml) (Alcon, Fort Worth, Texas) was injected into the median vein, angiography was started as soon as fluorescein was detected in the conjunctival vessels. The magnification was 16x. The time between the first photographs using the 40-SL and the last using Model-211 was two months.

Results

Flash intensity - The maximum flash intensities for Model-211, the 40-SL, and the SC-1200 were 500,000, 96,000, and 26,000 lux, respectively (Table 1). With an exciter filter and light-scattering plate fixed to each device as in actual photography, Model-211 emitted a flash intensity of 22,000 lux; the 40-SL, 5,060 lux; and the SC-1200, 4,900 lux.

Light transmission - The maximum light transmission levels between the objective lens and the camera of Model-211, the 40-SL, and the SC-1200 were 350, 120, and 66 lux, respectively (Table 2). When the relationship between the photographic magnification and the light transmission was examined, all three devices showed maximum light transmission at the most frequently used magnification (16x). The SC-1200 had virtually no change in light transmission at any given photographic magnification and the 40-SL also showed no change at practical magnifications (6-16x); on the other hand, Model-211 showed a change in light transmission with each magnification.

Filter characteristics - When the characteristic curves of the filters were compared, the 40-SL showed a slight overlap of transmitted wavelengths at 488 – 509 nm (Fig. 4). The 40-SL uses a cut-off filter that did not regulate transmitted light in the long wavelength range. The SC-1200 and Model-211 filters showed no overlapping wavelengths and had curves characteristic of the narrow bandpass wavelength type in which the wavelength of transmitted light was totally regulated. When the percentages of transmitted light at the maximum absorbance wavelength of fluorescein (480 nm) and the maximum fluorescein wavelength (530 nm) were compared, the SC-1200 exhibited slightly higher levels, 90% at exciter and 85% at barrier. All devices had light transmission levels exceeding 80%.

Effective density range in response to fluorescein - When the ranges of discrimination were compared, Model-211 covered 0.9 x 10 to 0.4 x 10 g/ml; the 40-SL, 0.4 x 10^{-6} to 0.2 x 10 girl; and the SC-1200, 0.8 x 10^{-6} to 1.0 x 10^{-4} girl (Fig. 5). The minimum useful density of Model-211 (0.9 x 10-7 g/ml) was approximately five times the detection sensitivity of the 40-SL and 10 times that of the SC-1200.

Flash recharge time - The SC-1200 had the shortest recharge time of 1.0 second [150 watt seconds (Ws)] followed by 2.0 seconds (480 Ws) for Model-211, and 6.0 seconds (960 Ws) for the 40-SL.

Clinical applicability - Model-211 and 40-SL detected abnormal blood vessels in the patient with rubeosis iridis diabetica immediately after fluorescein injection (Fig. 6a-c), whereas almost no abnormalities were detected with the SC-1200. Six seconds after the injection (Fig. 7a-c), all three devices detected extensive

Table 1. Flash intensity (lux) and the type of illumination system

Model-211		**40-SL** (Watt seconds)		**SC-1200**	
flash bulb	actual condition	flash bulb	actual condition	flash bulb	actual condition
94,000	1,800 (60)	12,000	600 (120)		
88,000	4,800 (120)	24,000	1,200 (240)		
266,000	10,400 (240)	48,000	2,400 (480)		
500,000	22,000 (480)*	96,000	5,060 (960)*	26,000	4,090 (150)*
diffuse illumination		diffuse illumination		direct focal illumination	

*Quantity of light used in the angiography of an actual case.
Actual condition, with exciter and light-scattering plate.

abnormal blood vessel growth. With the 40-SL, fluorescein leakage and abnormal blood vessels were slightly more difficult to discriminate than with the other devices. Twelve seconds after the injection (Fig. 8a-c), Model-211 and the SC-1200 still detected fluorescein leakage and abnormal blood vessels. Twenty-four seconds after the injection, it was virtually impossible to discriminate either abnormal blood vessels or fluorescein leakage with all three devices.

Discussion

Fluorescein angiography of the anterior segment can be performed by using a modified photo slit-lamp, in the present case, a Zeiss Model-211 modified by adding a filter pocket.

The results of the present study indicate that the modified Model-211 surpasses the other two devices in terms of basic optical characteristics. And when used clinically, Model-211 permits angiography with a small lens opening, which allows a greater depth of field. This is particularly important in capturing the full anterior chamber and the iris. Furthermore, the excellent flash intensity and light transmission capabilities of Model-211 are reflected in its minimum useful density, which allows it to detect weak fluorescence at the early phase of angiography. The bandpass filter used in Model-211 also prevents pseudofluorescence at long wavelengths [6-8]. Model-211 has a narrower range of recognition in the high-concentration region, ie, late-phase fluorescein angiography, than the other devices; however, fully satisfactory angiography still can be obtained even during the late phase without sacrificing image quality.

Both the 40-SL and the SC-1200 showed no change in light transmission at practical photographic magnifications, while the modified Model-211 showed light transmission change with each magnification. Therefore, both the 40-SL and the SC-1200 can be used to obtain angiograms by using a single flash exposure at different photographic magnifications; Model-211 requires adjustment of either the lens opening or the flash intensity at each photographic magnification, and, therefore, some user training is needed.

Table 2. Changes in light transmission through the photographic system at each photographic magnification (lux).

Model-211	40-SL (Magnification)	SC-1200
200 (5)	100 (6)	54 (6)
270 (9)	110 (10)	58 (10)
350 (16)	120 (16)	66 (16)
280 (27)	54 (25)	62 (25)
150 (50)	35 (40)	50 (40)

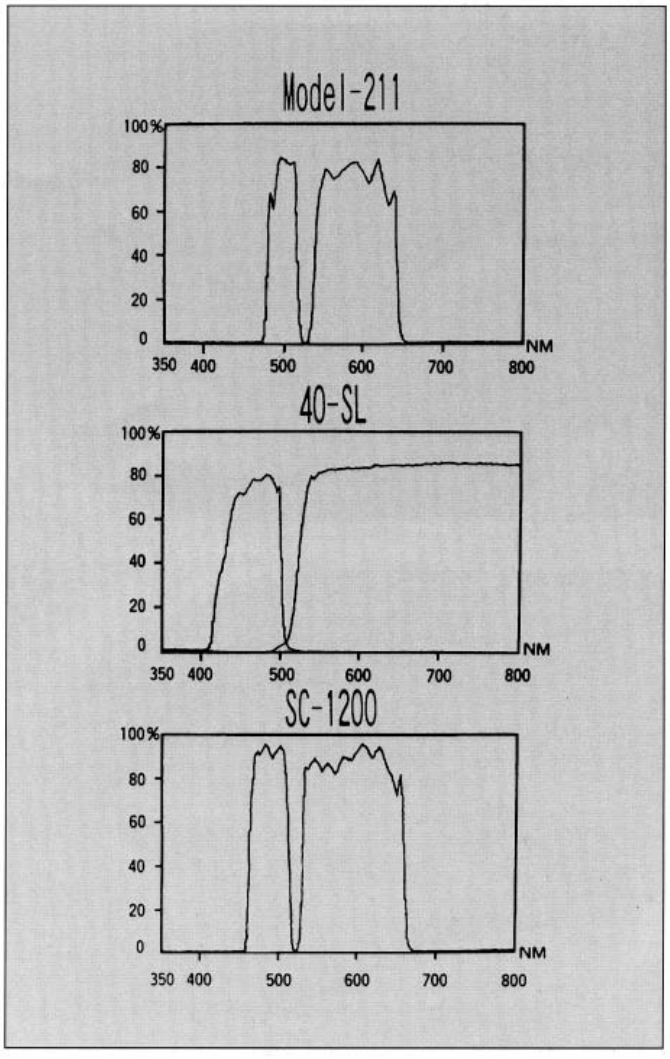


Figure 4: Comparison of the filter characteristics of each device.

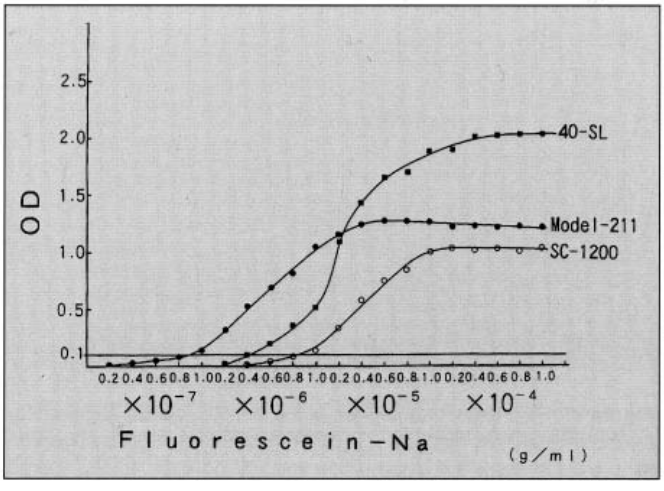
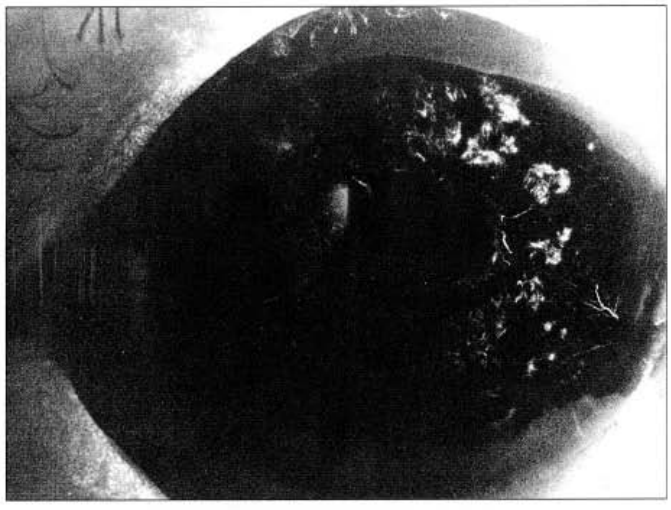
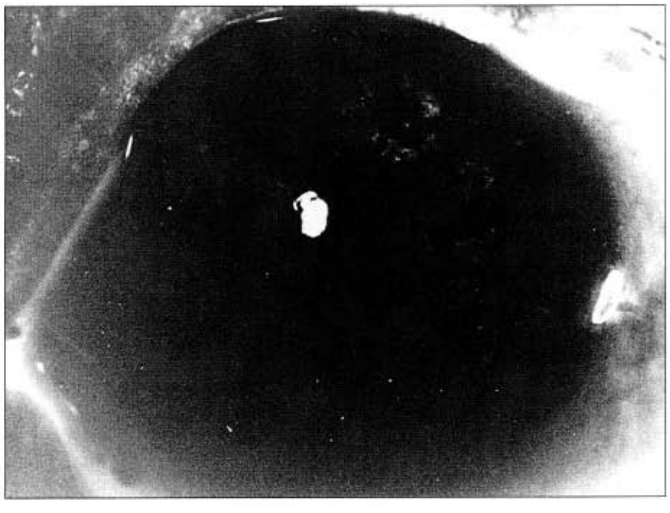


Figure 5: Effective density range in response to fluorescein (optical density) OD.





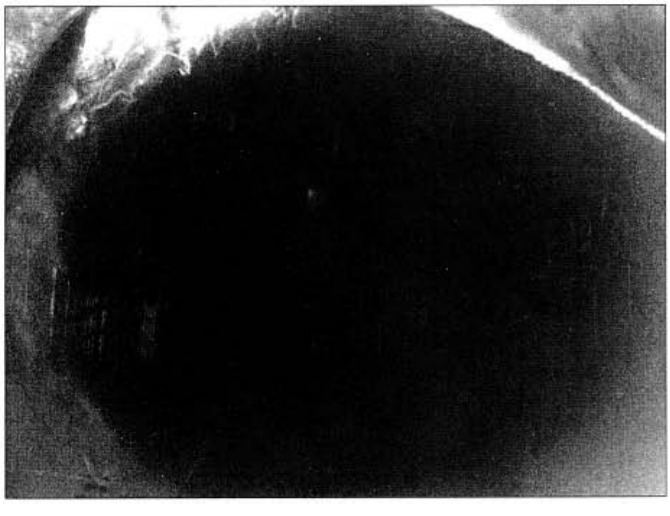
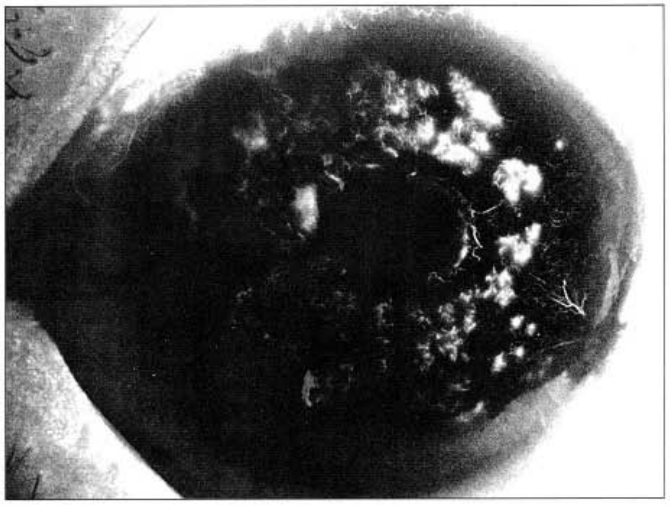
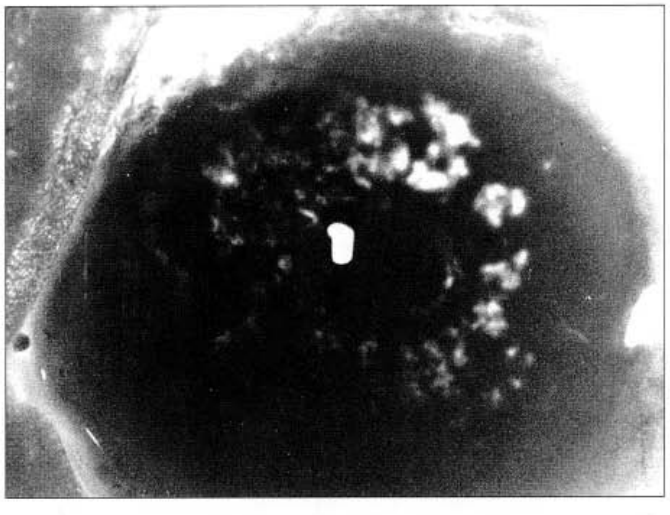


Figure 6: Fluorescein angiogram of the anterior ocular segment immediately after the injection. (Top) A- Model-211, fluorescence from minute blood vessels is clearly observed. (**Middle) B-** 40-SL, fluorescence from minute blood vessels is observed. **(Bottom) C-** SC-1200, almost no fluorescence is detected.





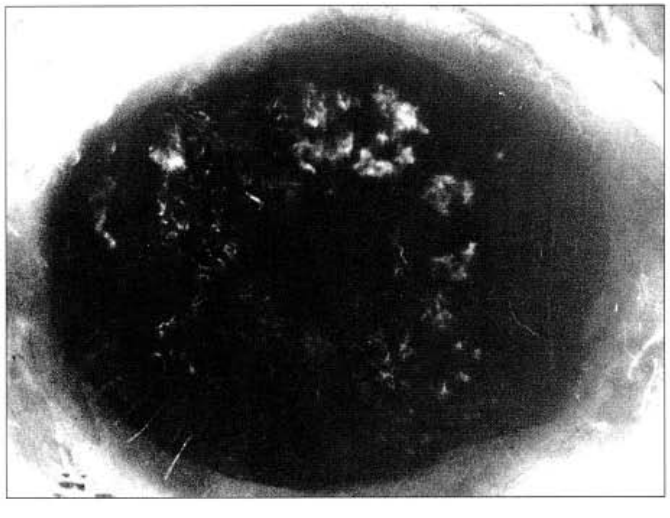


Figure 7: Fluorescein angiogram of the anterior ocular segment 6 seconds after the injection. (Top) A- Model-211, abnormal blood vessels and fluorescein leakage extending throughout the iris are observed. (**Middle) B-** 40-SL, although abnormalities are well documented, it is more difficult to detect abnormal blood vessels and fluorescein leakage than with the other devices. **(Bottom) C-** SC-1200, abnormal blood vessels and fluorescein leakage extending throughout the iris are observed.

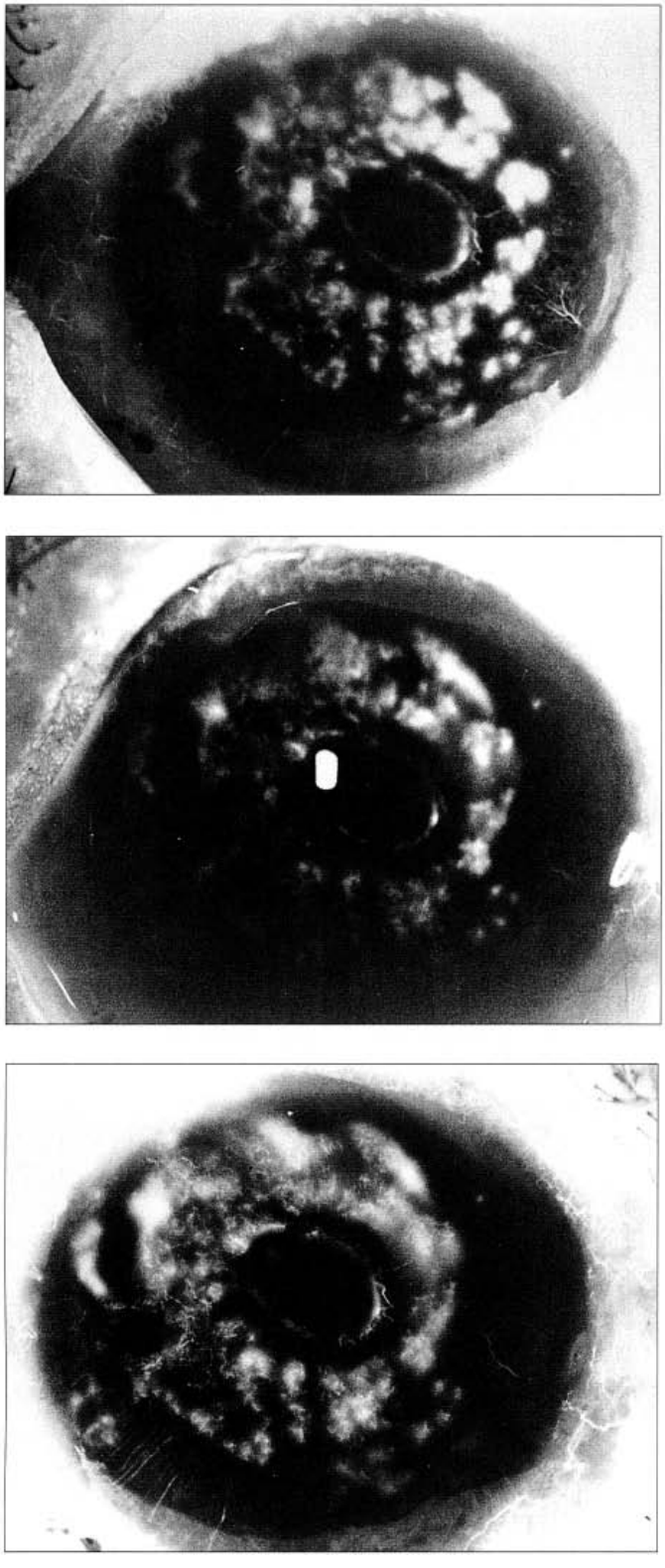


Figure 8: Fluorescein angiogram of the anterior ocular segment 12 seconds after the injection. **(Top)** A-Model-211, although considerably blurred due to fluorescein leakage, some abnormal blood vessels still can be seen. (**Middle) B-** 40-SL, abnormal blood vessels and fluorescein leakage are difficult to discriminate. The results at this time point are similar to those seen in Fig. 7b. **(Bottom) C-** SC-1200, although considerably blurred due to fluorescein leakage, some abnormal blood vessels are still observed.

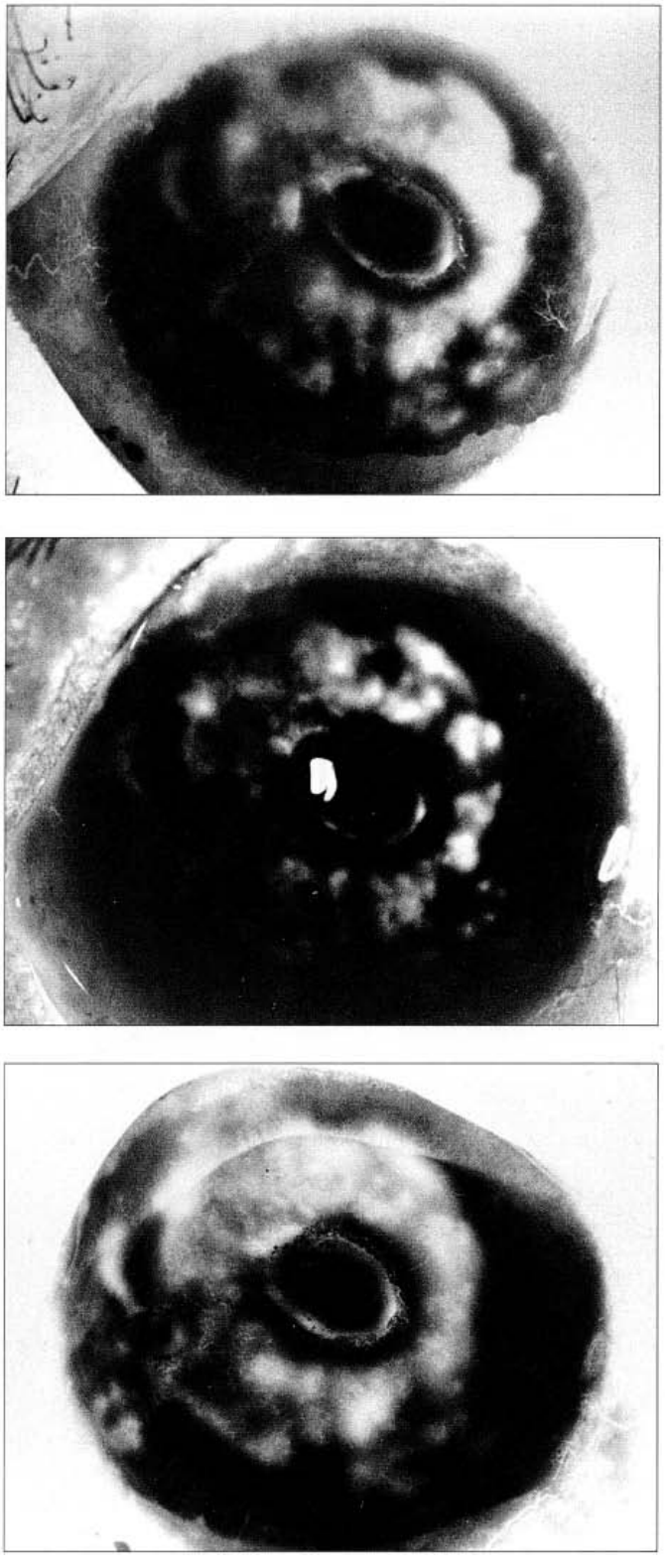


Figure 9: Fluorescein angiogram of the anterior ocular segment 24 seconds after the injection. Detection of abnormal blood vessels became impossible with all three devices due to massive fluorescein leakage.

Conclusion

In conclusion, although our modified Model-211 requires a certain degree of operator expertise, the image quality compared with that of other photo slit-lamp bimicroscopes clearly shows superior delineation of minute blood vessels.

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