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Experimental study of distinguishing small retinal haemorrhages from dust artefacts using HLS colour space

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ABSTRACT : *Many ophthalmologists consider it difficult to distinguish small retinal heamorrhages of early diabetic retinopathy from dust artefacts on fundus cameras. Photographs of the fundi of five patients with diabetic retinopathy were taken. We constructed the experimental device, which has an illumination optical system and a photographic optical system separated by a mirror having a hole with 4 mm diameter. The device consists of a canon EOS 50D camera, an EF 50mm f/1.8-2 camera lens, a Speedlite 270EX flash, an object lens, four double-convex lenses, two aperture stops and four artificial eyes. The eye ground is a half sphere made of polythene terephthalate painted by four mat colour sprays: red, white brown, ochre and yellow. Five fragments of house dust on the object lens were photographed under each artificial eye. The evaluation space of house dust was calculated using the HLS data obtained from the experimental device. The lightness of the HLS colour space helped in distinguishing dust from heamorrhage in all colour spectra. However, hue and saturation could distinguish dust from heamorrhage only under certain conditions.*
Keywords – *Dust artefacts, HLS colour space, small retinal haemorrhage and diabetic retinopathy*

I. INTRODUCTION

According to a research, the number of American patients with diabetes was 1.62 million in 1999, and US researchers estimated that in 30 years, the number would exceed 30 million [1]. In comparison, the number of Japanese patients with diabetes was 16.2 million in 2005 [2] and was predicted to reach 19.0 million in 2010. Many patients with diabetic retinopathy require regular ophthalmological examinations to prevent loss of eyesight [3]-[6]. Early diagnosis is very important [7]; however, many haemorrhages are minuscule [8]-[9], and detection of small retinal haemorrhages in patients with cloudy ocular media, such as a cataract, is difficult. Moreover, as shown in Fig. 1, magnified images taken with a fundus camera can be unclear.

Picture an image of the air in a room with numerous white spots on it [10]-[11]. These spots are reflections from the room dust particles caused by the camera's flash. Many of the room dust particles are out of focus and the flash reflected from them is stronger than the light reflected from a more distant object. These white spots are called dust artefacts [12]-[14]. If the camera's object lens is dusty, the reflected light from the objects will be obscured by dust particles and black spots will appear on the image. These black spots are also called dust artefacts.

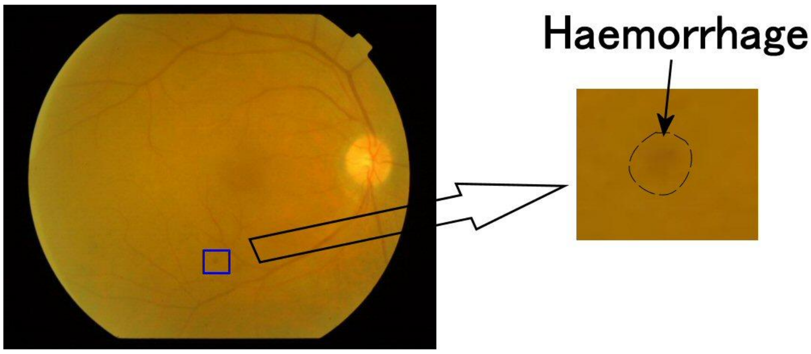

Fig.1 The area of small retinal haemorrhage in the fundus image of patient with diabetic retinopathy

II. PURPOSE

To distinguish the small retinal haemorrhages of early diabetic retinopathy from dust artefacts, we constructed an experimental device that has the same optical system as a fundus camera. Fragments of house dust on the lens were photographed under each artificial eye and the hue, lightness, saturation (HLS) colour space was analysed.

III. METHODS

1. Experimental device

The experimental device, as shown in Fig. 2, has an illumination optical system and a photographic optical system that are separated by a mirror having a hole with 4 mm diameter. The device consists of a canon EOS 50D camera, an EF 50 mm f/1.8-2 camera lens, a Speedlite 270EX flash, an object lens with 50 mm focal length, four double-convex lenses with 100 mm focal length, three aperture stops, a mirror and four artificial eyes.

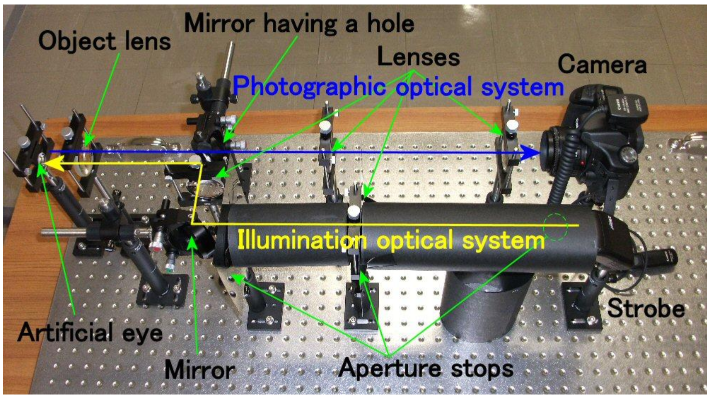

Fig.2 The experimental device

2. Optical system diagram of the experimental device

The optical system of the experimental device was analysed using optical design software, OpTaliX-LT 7.11. Fig. 3 shows an illumination optical system and a photographic optical system. The axial distance from eyeground to the image surface is 797.3 mm and that from eyeground to the strobe surface is 858.9 mm.

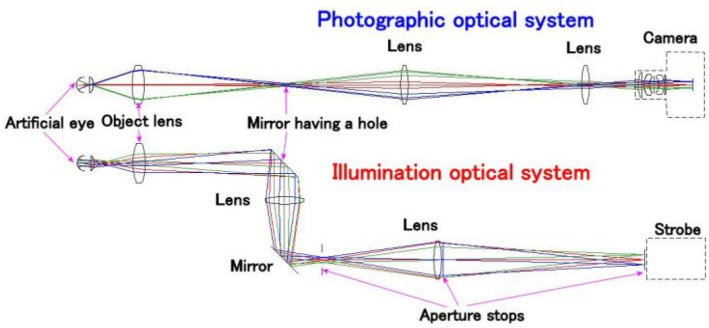

Fig.3 Optical system diagram of the experimental device

3. Artificial eyes

The artificial eye consists of a plane-convex lens with 22 mm focal length, a spacer and a hemispherical cup with 20 mm diameter. The hemispherical cup is made of polyethylene terephthalate and painted using four matt colour sprays: red, white brown, ochre and yellow (Fig. 4).

Fig.4 Artificial eyes

4. Photographing five fragments of house dust at each point under each artificial eye

We prepared five types of fragments of house dust measuring about 5 × 5 × 5 mm^3. These fragments were set on the lens at Points P1–P6, and then, the fragment at each point was photographed one by one, as shown in Fig. 5.

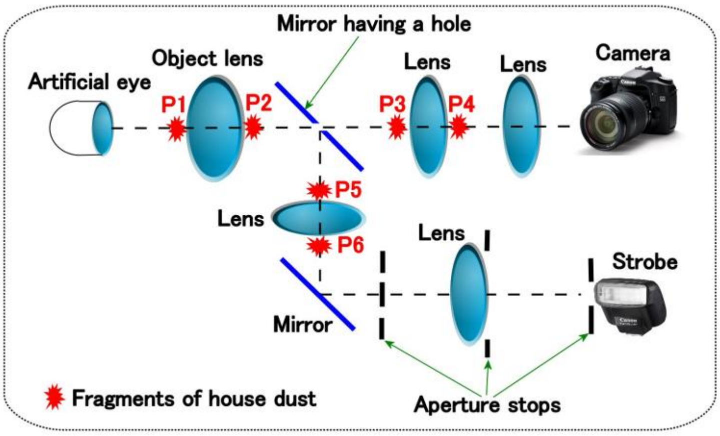

Fig.5 Fragments of house dust were set on the lens at Points P1–P6

5. Method to distinguish small retinal haemorrhages from dust artefacts by using the HLS colour space

Paint Shop Pro v. 8.0 was used to measure the HLS colour space of four areas, as shown in Fig. 6.

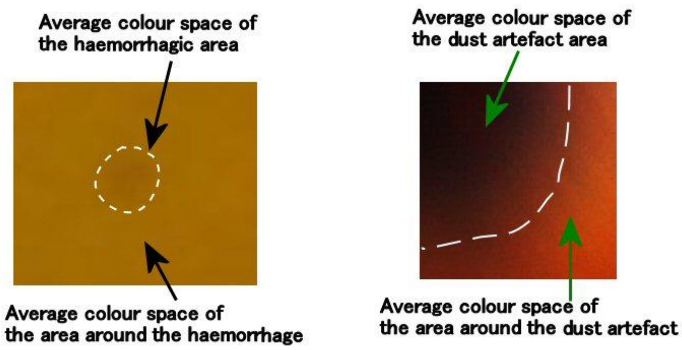

Fig.6 The average colour space of both the haemorrhagic area and the perihaemorrhagic area (left), and the average colour space of the dust artefact and the periartefact area (right)

6. Calculation of evaluation space for house dust using HLS data

Equation (1) shows the colour space for evaluation (Ev), which is the rate of change of CngDa to AveCngHm. CngDa is the colour space change in the dust artefact area and AveCngHm is the average of the colour space change in the haemorrhage area [15]. Greater the absolute values of EvH, EvL and EvS, greater is the extent to which the HLS colour space can be used to distinguish small haemorrhages from dust artefacts .

$$\mathbf{Ev} = \begin{bmatrix} EvH \\ EvL \\ EvS \end{bmatrix} \cdots (1)$$

IV. RESULTS

1. Changed colour spaces of the haemorrhagic area

The fundi of five patients with diabetic retinopathy were photographed. Fig. 7 shows 10 images of small retinal haemorrhagic areas clipped from the five fundus photographs.

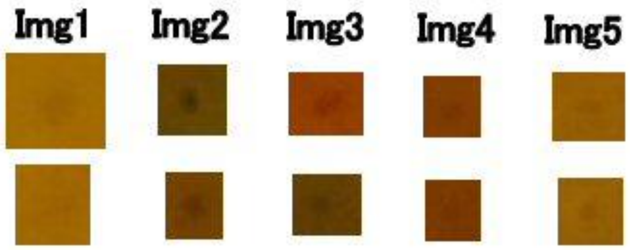

Fig.7 Ten images of the small haemorrhagic area of patients with diabetic retinopathy

2. Changed colour spaces of the dust artefact area

Four different coloured artificial eyes were photographed five times with a fragment of house dust set on the lens at one of the Points P1–P6. We obtained a total of 120 images and analysed them. Fig. 8 shows 24 images of the dust artefact areas clipped from the artificial eye photographs.

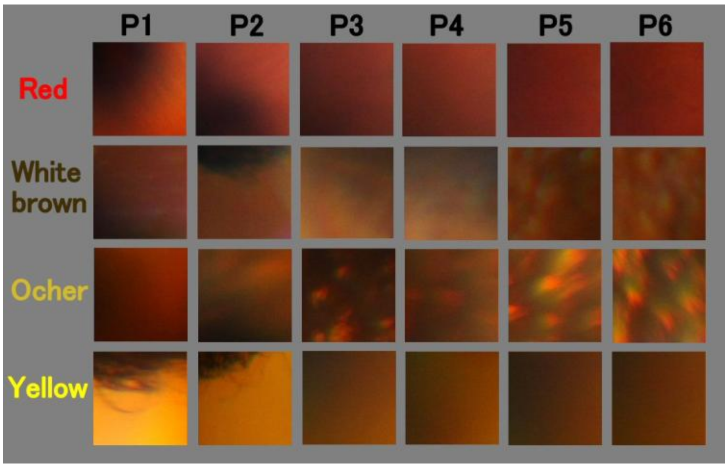

Fig.8 24 images of the dust artefact clipped from the artificial eye photographs

3. Calculation of evaluation space for house dust on the photographic optical system by using the HLS data obtained from the experimental device

Fig.s 9, 10 and 11 show the average EvH, EvL and EvS values, respectively. These values are obtained from the photographs of the dust particles at Points P1, P2, P3 and P4.

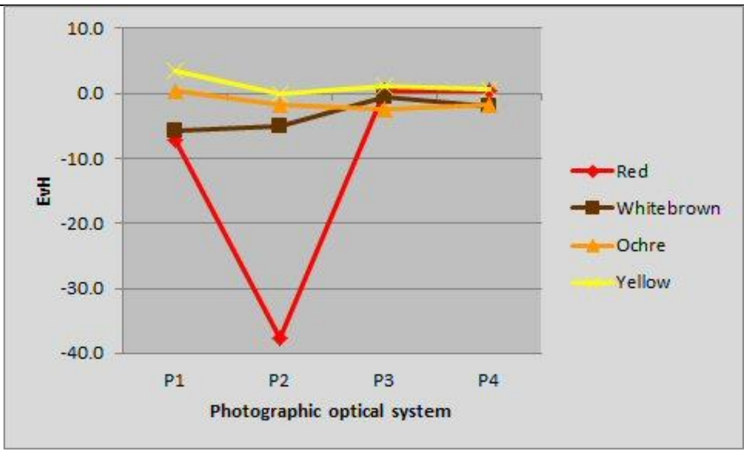

Fig.9 EvH values

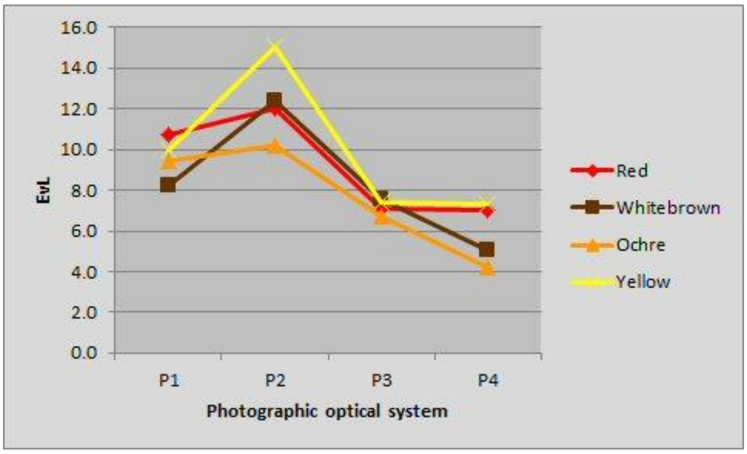

Fig.10 EvL values

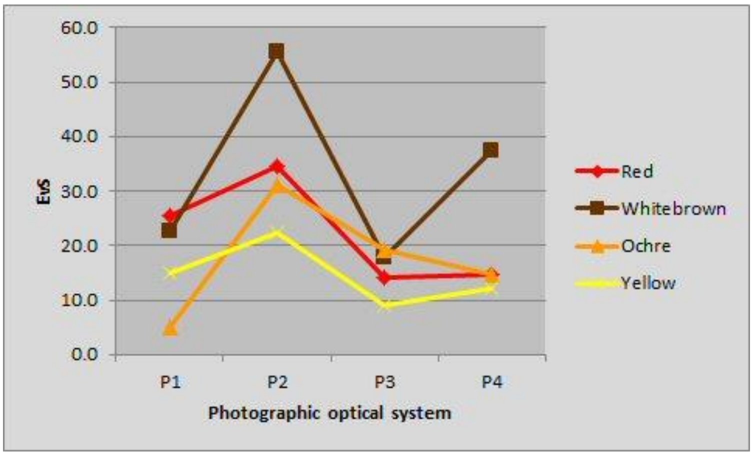

Fig.11 EvS values

4. Calculation of evaluation space for house dust on the illumination optical system by using the HLS data obtained from the experimental device

Fig. 12, 13 and 14 show the average EvH, EvL and EvS values, respectively. These values are obtained from the photographs of the dust particles at Points P1, P2, P5 and P6.

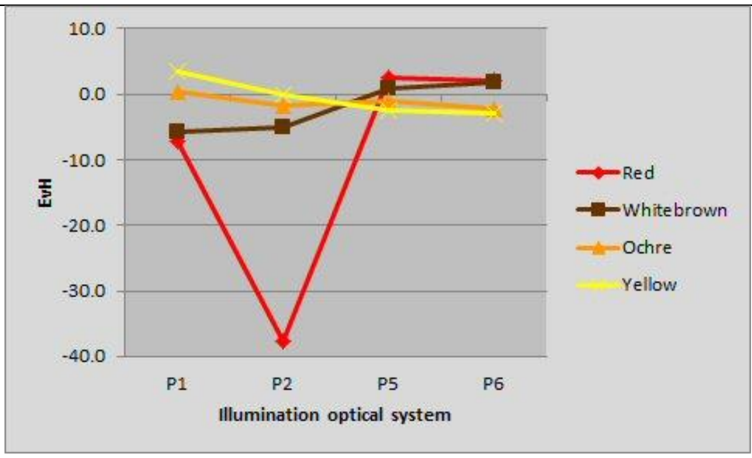

Fig.12 EvH values

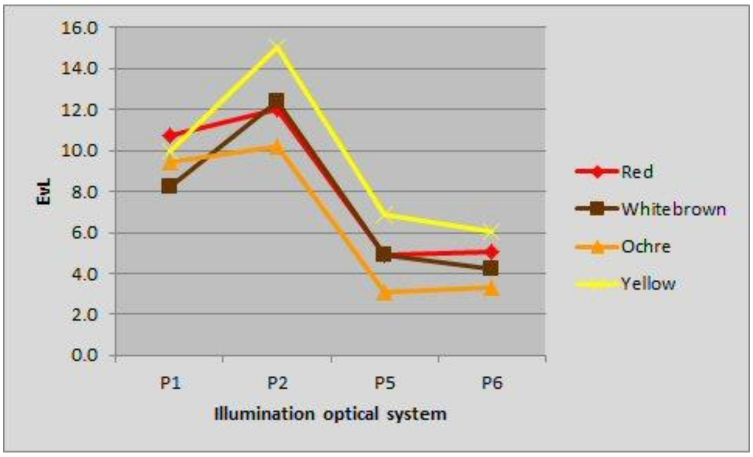

Fig.13 EvL values

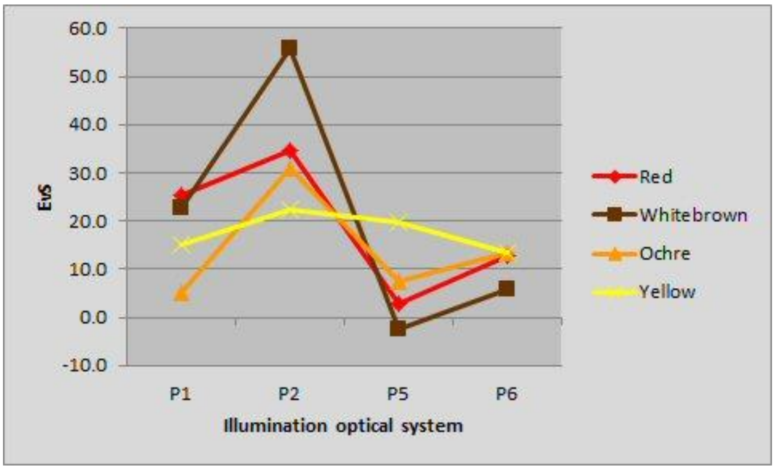

Fig. 14 EvS values

V. CONCLUSION

We constructed an experimental device having the same optical system as a fundus camera, and four different coloured artificial eyes were photographed using this. We investigated various methods to distinguish small retinal haemorrhages of diabetic retinopathy from dust artefacts by using the HLS colour space. In the HLS colour space, lightness and saturation enabled distinction of haemorrhages from dust artefacts under almost all conditions; however, hue enabled this distinction under certain conditions only.

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